CONSTRUCTION CONSIDERATIONS

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The integrity of a shoring system, like any other structure, is dependent on the quality of the actual construction as well as the adequacy of the design. Frequent and thorough inspection of the excavation and the shoring system during all stages of construction must be performed by qualified personnel. An awareness of changing conditions is essential.

1. Prior to the beginning of excavation work, become familiar with all aspects of the approved plans, location of the work, assumptions made, available soils data, groundwater conditions, surcharge loads expected, sequence of operations, location of utilities and underground obstructions, and any other factors restricting the work at the site.

2. Since the primary function of shoring is the protection of the workmen and adjacent property, it is essential that the inspector be knowledgeable of the minimum safety requirements.

3. Check the soil being excavated to see that it is the same material as anticipated.

4. Check for changes in ground water conditions.

5. As the excavation progresses be alert for indicators of distress such as cracking of members or subsidence near the excavation.

6. If the excavation is sloped back, without shoring, the need for inspection remains. Sloughing and cave-ins can occur.

7. For shored excavations, check the shoring members for size and spacing as shown on the approved plans. Any sequence of operations shown on the plans must be followed. Check for full bearing at ends of jacks and struts and make sure that they are secure and will not fall out under impact loads. Also check members for bending, buckling, and crushing.

8. Manufactured products, such as hydraulic struts, jacks, and shields should be installed and used according to the manufacturer recommendations.

9. If a tieback system is used, the tiebacks should be placed as per approved plan and preloaded to avoid overloading individual ties. If cables are used as tiebacks, they should not be wrapped around sharp corners. Thimbles should be used and cable clamps installed properly.

10. Surcharge loads need to be monitored to verify that such loads do not exceed the design assumptions for the system.

11. Weather conditions may have adverse effects on excavations and some materials, especially clays, may fail due to change in moisture content.

12. Good workmanship makes an excavation safer and easier to inspect, Trouble spots are easier to detect when the excavation is uniform and straight.

13. Vibratory or dynamic loadings from pile driving or blasting operations require special attention to soil or shoring.

14. Utility owners should be notified prior to commencement of work if their facilities are within 5 times the excavation depth.

Underground Service Alert

Northern California (USA)	l-800-642-2444
Southern California (USA)	l-800-422-4133

South Shore Utility

Coordinating Council (DIGS)	l-800-541-3447

15. Encourage the use of benchmarks to monitor the shoring system before, during, and after ground movements in the vicinity of excavations (within a distance of 10 times the excavation depth). Ground settlements accompany shoring deflections.

ALLOWABLE WORKING STRESSES

Timber

Construction Safety Orders defining lumber and allowable stresses are included in the Appendix C to Section 1541.1 (See Appendix A of this manual). Member substitution for shoring systems to be used in conjunction with timber tables of Appendix C to Section 1541.1 requires that they be manufactured members of equivalent strength. Some alternate crossbracing manufactured members are shown in Appendix E to Section 1541.1 of the Safety Orders (See Appendix A of this manual).

Briefly, except for scaffold plank, Select or Douglas Fir l equivalent lumber or timber shall be suitable for 1,500 psi bending stress l The tables for timber shoring in Appendix C to Section 1541.1 of the Safety Orders permit an allowable bending stress of not less than 850 psi for mixed oak or equivalent wood.

When shoring plans designed by a qualified engineer do not specify stress limitations or list type of lumber (timber) OSC will review the plans assuming Douglas Fir Larch (North) Group II with the following stress limitations:

$F_c = 480{,}000\ (L/D)^2$ psi	Compression Parallel to Grain Not to exceed 1,600 psi
F_b = 1,800 psi	Flexural (bending) Reduced to 1,500 psi for members with a nominal depth of 8 inches or less.
F_t = 1,200 psi	Direct Tension
$F'_\perp$ = 450 psi	Compression Perpendicular to Grain
V = 140 psi	Horizontal Shear
E = 1.6 X 10^6 psi	Modulus of elasticity Use 1.2 X 10^6 psi for wet or green-timber
Overstress:	Permit 33% overstress for short term loadings (see exceptions in "Shoring General Procedure," Chapter 5).

Lesser stress values shown on the shoring plans or in the accompanying calculations will be used for review.

When lumber (timber) type is listed or shown on the shoring plan without allowable stress values the "National Design Specification For Wood Construction" will be used as a guide. If the specific, lumber grading is not included, low allowable stress values will be used.

Railroads allow 1,700 psi maximum in lieu of l,800 psi for flexural stress. Shoring adjacent to railroads is to be designed and reviewed in accordance with railroad requirements. Specific railroad requirements are included in Appendix C.

Steel

Refer to current AISC specifications. If grade of steel is unknown, Use A36 (F_y = 36 ksi, E = 30 x 10^6).
Steel sheet piling: use Grade A328 steel for which F_b = 25 ksi, unless specific informaton is furnished for higher grade steel.

Aluminum

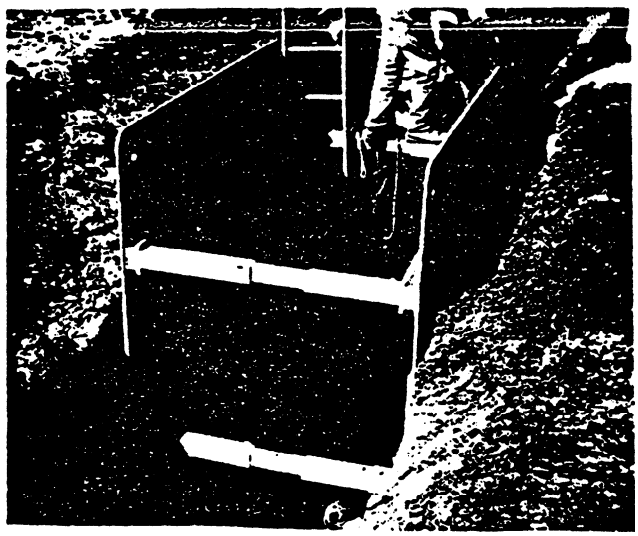
Refer to current aluminum design references.

Concrete

Use current structural concrete design criteria.

Connectors

For timber connectors use the current National Design Specification for Wood Construction, National Forest Products Association. OSC allows the single shear value to be 0.75 of the NDS tabular value for double shear connection (in lieu of 0.50).
For steel, refer to current AISC Specifications.



MECHANICS OF STRESS ANALYSIS

Use the accepted structural mechanics formulas and theories. Check members of the shoring system for flexure, shear, compression, and bearing. Check the system (with soil) for stability. Approximate calculations are satisfactory for most shoring systems.

Common structural mechanics formulas:

Flexural stress (bending)	$f_b = M/S$	M = Bending Moment S = Section Modulus
Axial Compression	$f_C = P/A$	P = Applied Load A = Area of Member
Timber		
Compression ⊥ to grain	$f_\perp = P/A$	
Horizontal Shear	$V = (1.5)w(L/2 - b/2 - d)/A$	

L = span length (center to center)
b = thickness of supporting member or length of bearing area, whichever is less
d = depth of member for which shear is being investigated.
W = unit load

For lagging use simple span moments. Multiply all loads by 0.6 to account for soil arching. $M = 0.6wL^2/8$

In many cases the effective span for lagging will be less than the spacing of supports.

For interior moments of uniformly loaded continuous uprights, walers, or rails, $M = wL^2/10$ may be used.

For cantilevers: M = wL2/2

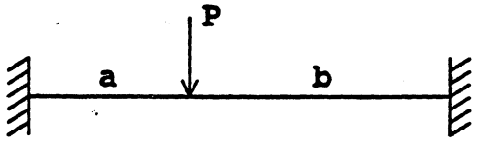
The Design Earth Pressure Diagram will be the sum of the basic earth pressure, surcharge loads, and any other applicable loads (such as ground water).

Since calculating earth pressures is not precise, an irregular-shaped composite diagram may be simplified by using standard geometrical shapes (rectangles, triangles, etc.).

LOADING DIAGRAMS

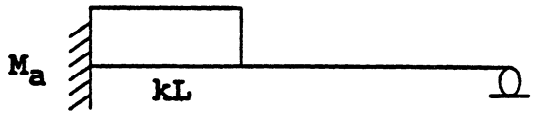
An approximation is made when triangular loads are converted to concentrated loads. For an exact solution use the following formulas to calculate fixed end moments:

$M_a = Pab^2/L^2$

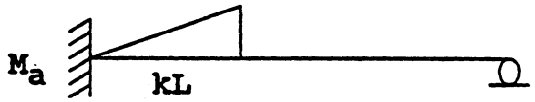


$M_b = Pa^2b/L^2$

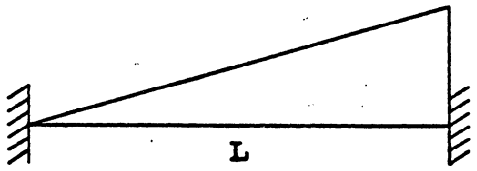
$M_a = wL^2k^2(4 - 4k + k^2)/8$



$M_a = wL^2k^2(40 - 45k + 12k^2)/120$

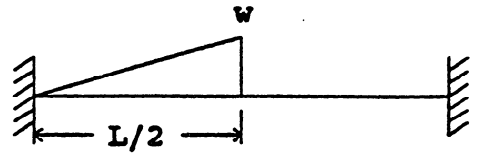


$M_a = wL^2/30$



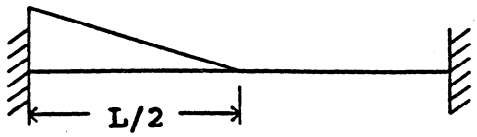
$M_b = wL^2/20$

$M_a = wL^2/30$



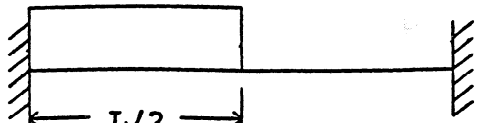
$M_b = 3wL^2/160$

$M_a = 23wL^2/960$

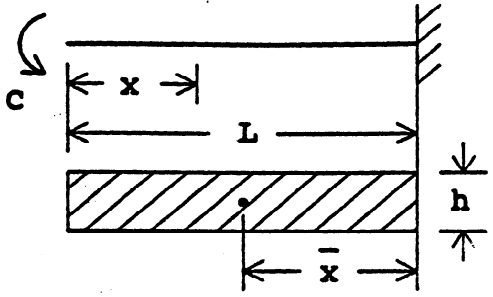
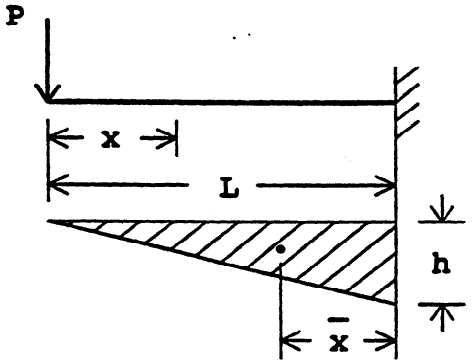
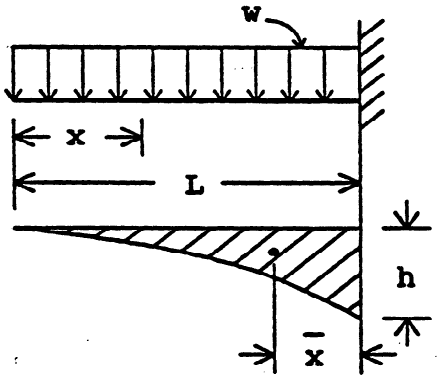
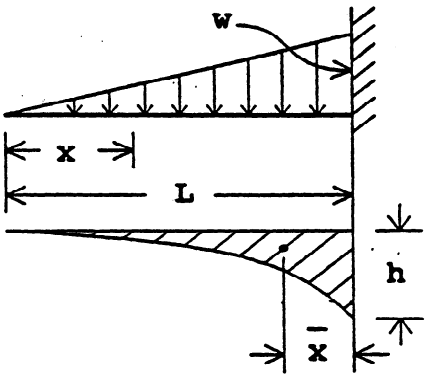


$M_b = 7wL^2/960$

$M_a = 11wL^2/192$



$M_b = 5wL^2/192$

TYPE OF LOADING	CANTILEVER BEAM	EQUATIONS
Couple		$M = -C$ Area = Lh $\bar{x} = L/2$ $h = -C$
Concentrated		$M = -Px$ Area = Lh/2 $\bar{x} = L/3$ $h = -PL$
Uniformly Distributed		$M = -wx^2/2$ Area = Lh/3 $\bar{x} = L/4$ $h = -wL^2/2$
Uniformly Varying		$M = -wx^3/6L$ Area = Lh/4 $\bar{x} = L/5$ $h = -wL^2/6$

ENCROACHMENT PERMIT PROJECTS

This category of work includes shoring for projects by others, either within the State highway right of way, or adjacent to State highways. The work is done under an Encroachment Permit issued to the Contractor, Builder and/or Owner by the District Permits Engineer,

Usually a condition of a permit is that appropriate plans of the proposed shoring system be prepared and submitted to the State Permits Engineer for review and approval before work may be started.

Many of the encroachment permit projects are quite simple, like pipe trenches of nominal depth which may conform to the Standard DOSH Details. However, complex shoring systems will be needed for large building excavations, multiple tier tie back systems, etc.

The District Permits Engineer, on receipt of an implication for an encroachment permit, will decide if he needs technical assistance to review the plans. The Permits Engineer may ask District Construction to complete the review if the conditions are such that the Standard DOSH Details may apply and the plans conform to these Details.

For more complex shoring systems, District Construction or the Permits Engineer may request technical review assistance from a structures person. For a very complex major shoring project the Permits Engineer will usually route the plans to the Office of Structures Maintenance for review. Structures Maintenance, in turn, may then forward the plans either (or both) to Structure Design or Office of Structure Construction for structural review. Encroachment Permit shoring plan review is an ongoing engineering responsibility.

The inspection of the actual work in the field is handled in a similar way. Intermittent inspection may be handled by the District. For average or simple projects, this is usually on an informal basis.

For major encroachment permit projects the District may request that OSC assign an Engineer as a representative of the District Permits Engineer.

A part of the field review or monitoring will be to see that the Contractor and/or owner have the proper permits.

If it is necessary to request a Contractor to make a major correction or improvement of work during the course of construction, remember that the administrative or control procedure is different from State

Construction Contracts. The field reviewer is a representative of the Permits Engineer, not the Resident Engineer. If there are difficulties the Permits Engineer can always withdraw an Encroachment Permit, which would have the effect of stopping work. It is suggested that discussions be held with the area structure construction engineer.

Note that consultants who prepare shoring -plans for Encroachment Permit projects do not necessarily use the recommended allowable stresses given in this manual. In making a review, keep this in mind. Acceptance should be based on nothing less than that required for a State project, with due considerationbeing given to the background of the Contractor, the work to be done, and the degree of risk involved. Remember, geotechnical engineering is not an exact or precise science.

In order for the State to review and approve a Contractor's shoring system, a plan of work to be done must be submitted. As a minimum the shoring plan will contain the following information:

ENCROACHMENT PERMIT NO. (Contractor)

Contractor:	(Name, address, phone)
Owner:	For who the work is being done. Include Contract No. or Designation.

OWNER ENCROACHMENT PERMIT NO.

Location:	Road, street, highway stationing, etc. This shows the scope or extent of the project.
Purpose:	Describe what the trench or excavation is for (24" sewer line, retaining wall, etc).
Soil Profile:	A description of the soil including the basis-of identification; surface observation, test borings, observation of adjacent work in same type of material, reference to a soils investigation report, etc. In the absence of specific soils data the reviewer must assume very conservative values. Include any observed ground water data.

Surcharge Loadings:

Any loads, including normal construction loads, that are adjacent to the excavation or trench should be identified and shown on the plans with all pertinent dimensions; examples are highways, railroads, existing structures, etc. The lateral pressures due to these loads will then be added to the basic soil pressures. The type of loading will also effect the type of shoring that can be accepted (an adjacent building will necessitate restriction of movement in the shoring system for example). The minimum surcharge is to be used where not exceeded by above loading considerations.

Trenching & Shoring Plan:

A complete description of the shoring system including all members, materials, spacing, etc. As most trenches are rarely uniform in depth and width, it might become necessary to average various sections. However, there are practical limits as to how much averaging is acceptable and it may be necessary to break the trench into smaller units which are similar in size.

Information may be in the form of a drawing, or referenced to the applicable portions of the Construction Safety Orders.

If a shoring system varies from Title 8 of the Safety Orders, then by law (California Code), a Professional Engineer (Civil or Structural) must prepare the shoring plans.

Refer to the order of work and/or traffic control plan if pertinent to the shoring system.

The plan for simple trench work can be in the form of a letter which covers the items required.

CONSTRUCTION CONSIDERATIONS

Manufactured Data:

Catalogs or engineering data for a product should be identified in the plan as supporting data. All specific items or applicable conditions must be outlined on the submittal (yellow or high lighting is one way to do this).

Construction Permit:

Any plan or information submitted should confirm that a permit has been secured from DOSH to perform the excavation work. This is not an approval of the shoring system by DOSH.

Inspection: Permit projects will require the same level of inspection that is used on contract work; watching for changing soil conditions, member overstress, potential shoring movement, etc.

The State Department of Transportation will review a Contractor's Shoring Plan in accordance with applicable State Specifications and the Construction Safety Orders, Deviations from DOSH or different approaches will be considered, providing adequate supporting data (calculations, soils investigations, manufacturer's engineering data and references) are submitted. The "CALIFORNIA TRENCHING AND SHORING MANUAL" will be used as a guide for plan review and approval.

CONCLUSIONS

The Department has an obligation with respect to trenching and shoring. work. Be informed of legal responsibilities and requirements (Refer to Chapter 1).

Soil Mechanics (Geotechnical Engineering) is not a precise science. Be aware of the of effects assumptions can make. Simplified engineering analysis procedures can be used for much of the trenching and shoring work that will be encountered.

The actual construction work is of equal importance to the engineering design or planning. The Contractor and the Engineer must always be alert to changed conditions and must take appropriate action. Technical assistance is available. The Engineer at the jobsite must be able to recognize when he needs help. The need for good engineering judgment is essential.

Work involving railroads requires additional controls and specific administrative procedures.

Following is a summary of D.0.T: policy in regard to trench and excavation shoring work:

1. The law (State Statute, Section 137.6) requires that a California registered professional engineer review the Contractor's plans for temporary structures in connection with State Highway work. Shoringplans areincluded in this category.

2. The Resident Engineer will ascertain that the Contractor has obtained a proper excavation or trenching permit from DOSH before any work starts, and that the permit (or copy) is properly posted at the work site.

3. If the trench is less than 20 feet deep and the Contractor submits a plan in accordance with the Construction Safety Order Details, it is not necessary to have the plans prepared by a Professional Engineer. The Resident Engineer will confirm that the Contractor's plan does indeed conform to the DOSH Details and need not make an independent engineering analysis.

4. If a trench is over 20 feet in depth, the DOSH Details cannot be used; the plans must be prepared by a Professional Engineer.

When shoring plans are designed by firms specializing in temporary support systems and soil restraint (including sloping), good engineering judgement is to prevail for review. Shoring designed by such firms will often be less conservative than would shoring designed by conservative use of this manual.

6. If the Contractor shoring plan deviates from the Construction Safety Order Details, the plan must be prepared by a California registered professional engineer and the reviewing Engineer will make a structural analysis.

7. For any shoring work which requires review and approval by a Railroad; the Sacramento OSC Office will be the liaison between the project and the Railroad. The Structure Representative will submit the Contractor shoring plans to OSC Sacramento after review. The review should be so complete that the plans are ready for approval.

The Structure Representative should inform the Contractor of the proper procedure, and the time, required for Railroad review and approval.

8. Any revisions to plans should be done by the plan originator or by his authorized representative. Minor revisions may be made on plans but the revisions should be initialed and dated by the person making the changes.